US009319697B2

(12) **United States Patent**
Henry et al.

(10) **Patent No.: US 9,319,697 B2**
(45) **Date of Patent: Apr. 19, 2016**

(54) **CODING AND DECODING IMAGES WITH SIGN DATA HIDING**

(71) Applicant: **DOLBY INTERNATIONAL AB**, Amsterdam Zuidoost (NL)

(72) Inventors: **Felix Henry**, Saint Gregoire (FR); **Gordon Clare**, Pace (FR)

(73) Assignee: **DOLBY INTERNATIONAL AB**, Amsterdam Zuidoost (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/492,950**

(22) Filed: **Sep. 22, 2014**

(65) **Prior Publication Data**

US 2015/0010076 A1 Jan. 8, 2015

Related U.S. Application Data

(63) Continuation of application No. 14/356,804, filed as application No. PCT/FR2012/052551 on Nov. 6, 2012.

(30) **Foreign Application Priority Data**

Nov. 7, 2011 (FR) 11 60114

(51) **Int. Cl.**

H04N 19/167	(2014.01)
H04N 19/176	(2014.01)
H04N 19/147	(2014.01)
H04N 19/46	(2014.01)
H04N 19/463	(2014.01)
H04N 19/467	(2014.01)
H04N 19/196	(2014.01)
H04N 19/50	(2014.01)
H04N 19/91	(2014.01)
H04N 19/85	(2014.01)

(52) **U.S. Cl.**

CPC ***H04N 19/167*** (2014.11); ***H04N 19/147*** (2014.11); ***H04N 19/176*** (2014.11); ***H04N 19/197*** (2014.11); ***H04N 19/46*** (2014.11); ***H04N 19/463*** (2014.11); ***H04N 19/467*** (2014.11); ***H04N 19/50*** (2014.11); ***H04N 19/85*** (2014.11); ***H04N 19/91*** (2014.11)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,379,608	B2	5/2008	Marpe et al.
8,315,310	B2	11/2012	Shi
8,767,824	B2	7/2014	Misra et al.

(Continued)

OTHER PUBLICATIONS

Clare, et al. "Sign Data Hiding," JCTVC-G271, 7th Meeting: Geneva, CH, Nov. 21-30, 2011.*

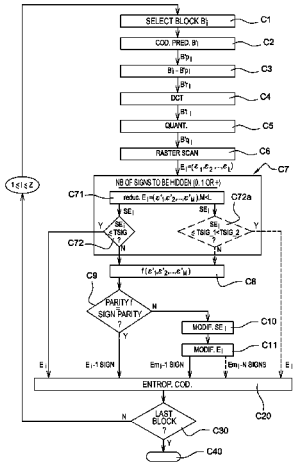
(Continued)

Primary Examiner — Huy T Nguyen
Assistant Examiner — Michael J Hess
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

A method is provided for coding at least one image split up into partitions, a current partition to be coded containing data, at least one data item of which is allotted a sign. The coding method includes, for the current partition, the following steps: calculating the value of a function representative of the data of the current partition with the exclusion of the sign; comparing the calculated value with a predetermined value of the sign; as a function of the result of the comparison, modifying or not modifying at least one of the data items of the current partition, in the case of modification, coding the at least one modified data item.

12 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

9,001,888	B2	4/2015	Henry et al.	
2004/0228404	A1	11/2004	Yu	
2007/0080832	A1	4/2007	Yang et al.	
2008/0246637	A1	10/2008	Chen et al.	
2012/0106647	A1	5/2012	Jung	
2012/0224631	A1	9/2012	Jung	
2012/0230417	A1	9/2012	Sole Rojals et al.	
2012/0230418	A1	9/2012	Sole Rojals et al.	
2013/0188725	A1*	7/2013	Wang et al.	375/240.18
2013/0336409	A1*	12/2013	He et al.	375/240.25
2014/0233655	A1	8/2014	Jung	
2014/0314144	A1	10/2014	Henry	
2014/0348223	A1	11/2014	Henry et al.	
2014/0348237	A1	11/2014	Thiesse	
2015/0010089	A1	1/2015	Henry et al.	
2015/0195568	A1	7/2015	Henry et al.	

OTHER PUBLICATIONS

Sole, et al. "Transform Coefficient Coding in HEVC," IEEE Transactions on Circuits and Systems for Video Technology, vol. 22, No. 12, Dec. 2012, pp. 1765-1777.*

Hadar O, et al. "Rate distortion optimization for efficient watermarking in the DCT domain," 2008 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting, Piscataway, NJ, USA, Mar. 31, 2008 pp. 1-8.*

Hadar et al., "Rate distortion optimization for efficient watermarking in the OCT domain", Broadband Multimedia Systems and Broadcasting, 2008 IEEE International Symposium on, IEEE, Piscataway, NJ, USA, Mar. 31, 2008, pp. 1-8, XP031268612.

Kim et al., "Data Hiding on H.264/AVC Compressed Video", Image Analysis and Recognition; [Lecture Notes in Computer Science], Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 698-707, XP019097872.

Li et al., "A Reversible Data Hiding Scheme for JPEG Images", Sep. 31, 2010 (Sep. 21, 2010), Advances in Multimedia Information Processing—PCM 2010, Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 653-664, XP019151677.

Ma et al., "A Data Hiding Algorithm for H.264/AVC Video Steams Without Intra-Frame Distortion Drift", IEEE Transactions on Circuits and Systems for Video Technology, IEEE Service Center, Piscataway, NJ, US, vol. 20, No. 10, Oct. 1, 2010, pp. 1320-1330, XP011317382.

Paruchuri et al., "Joint optimization of data hiding and video compression", Circuits and Systems, 2008. ISCAS 2008. IEEE International Symposium on, IEEE, Piscataway, NJ, USA, May 18, 2008, pp. 3021-3024, XP031392649.

Thiesse et al., "Rate Distortion Data Hiding of Motion Vector Competition Information in Chroma and Luma Samples for Video Compression", IEEE Transactions on Circuits and Systems for Video Technology, IEEE Service Center, Piscataway, NJ, US, vol. 21, No. 6, Jun. 1, 2011, pp. 729-741, XP011325921.

International Search Report and Written Opinion dated Nov. 6, 2012 for corresponding International Application No. PCT/FR2012/052552 filed Jun. 11, 2012, 28 pages (with English translation).

International Search Report and Written Opinion dated Jan. 31, 2013 for corresponding International Application No. PCT/FR2012/052551, filed Jun. 11, 2012, 25 pages (with English translation).

Amonou et al., "Video coding technology proposal by France Telecom, NTT, NTT DoCoMo, Panasonic and Technicolor", 1st JCTVC meeting, Dresden, Apr. 2010 (JCTVC-A114), 42 pages.

Bossen, "Common test conditions and software reference configurations," 6th JCTVC meeting, Torino, Jul. 2011 (JCTVC-F900), 4 pages.

Cohen et al., "Low Complexity Embedding of Information in Transform Coefficients", 5th JCTVC meeting, Geneva, Mar. 2011(JCTVC-E428), 7 pages.

Thiesse et al., "Data hiding of Intra prediction information in chroma samples for video compression," Proc. IEEE International Conference on Image Processing, ICIP 2010, pp. 2861-2864, Hong Kong, Sep. 2010.

Office Action issued in U.S. Appl. No. 14/492,829 on Jan. 5, 2015, 11 pages.

Office Action issued in U.S. Appl. No. 14/356,804, on Nov. 28, 2014, 17 pages.

Notice of Allowance issued in U.S. Appl. No. 14/665,163 on Oct. 20, 2015, 6 pages.

Office Action issued in U.S. Appl. No. 14/356,799 on Oct. 19, 2015, 19 pages.

Notice of Allowance issued in U.S. Appl. No. 14/492,829 on Feb. 27, 2015, 7 pages.

Office Action issued in U.S. Appl. No. 14/356,804 on May 8, 2015, 13 pages.

Office Action issued in U.S. Appl. No. 14/665,163 on Jun. 19, 2015, 15 pages.

* cited by examiner

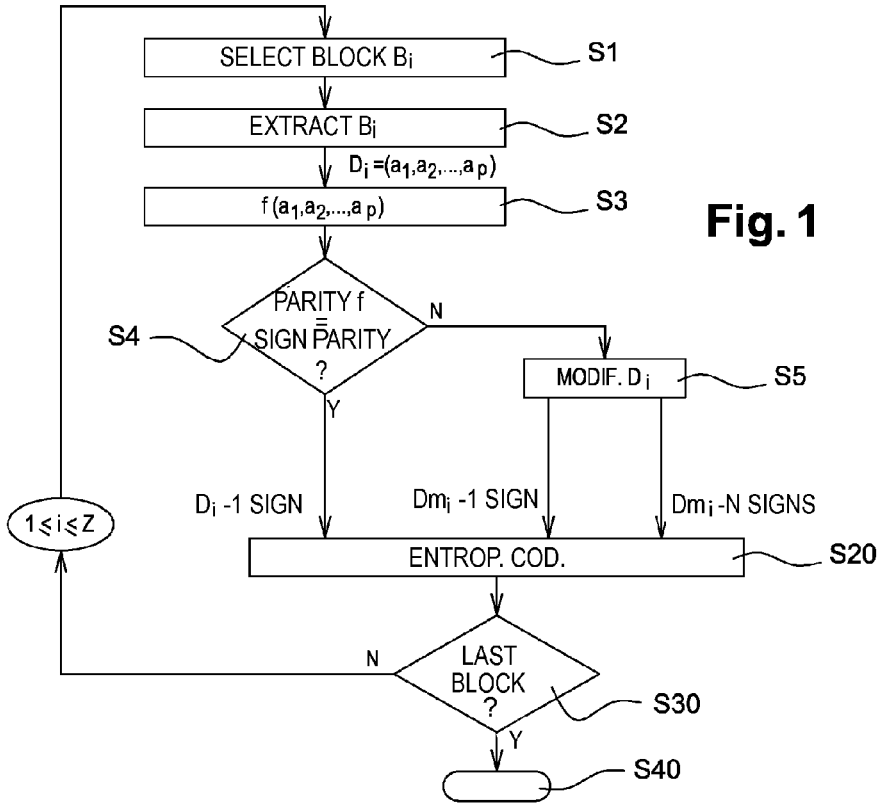

SELECT BLOCK Bi
S1
EXTRACT Bi
S2
Di =(a1,a2,...,ap)
f (a1,a2,...,ap)
S3
PARITY f
SIGN PARITY
?
N
Y
S4
MODIF. Di
S5
Di -1 SIGN
Dmi -1 SIGN
Dmi -N SIGNS
1≤i≤Z
ENTROP. COD.
S20
LAST
BLOCK
?
N
Y
S30
S40

Fig. 1

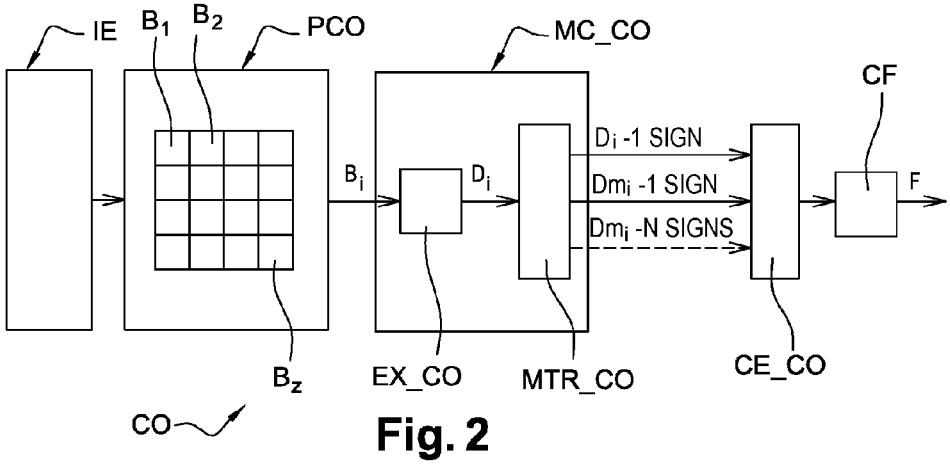

IE
B1
B2
PCO
MC_CO
CF
Bi
Di
Di -1 SIGN
Dmi -1 SIGN
Dmi -N SIGNS
F
Bz
EX_CO
MTR_CO
CE_CO
CO

Fig. 2

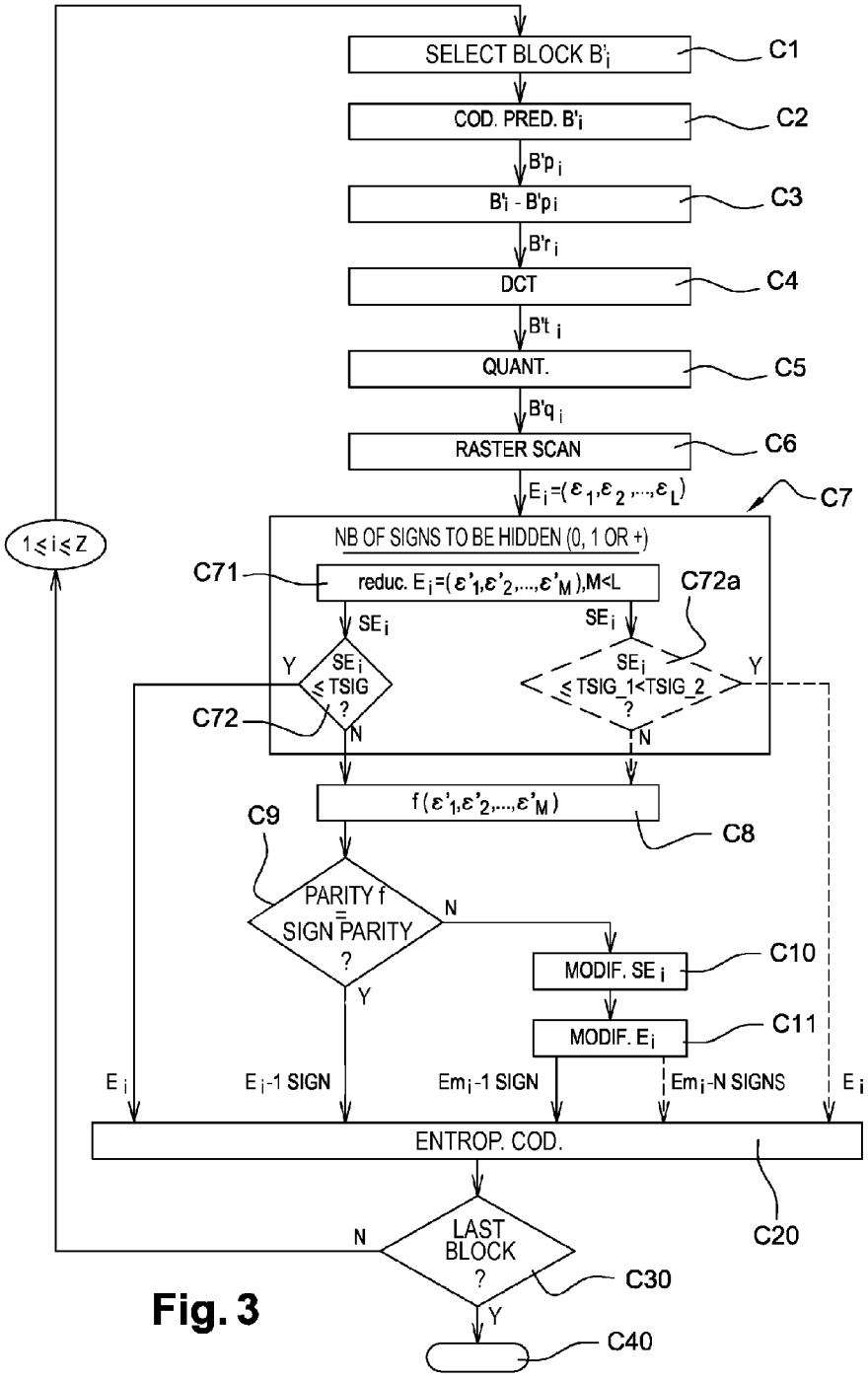

SELECT BLOCK B'i
C1
COD. PRED. B'i
C2
B'p i
B'i - B'p i
C3
B'r i
DCT
C4
B't i
QUANT.
C5
B'q i
RASTER SCAN
C6
Ei=(ε1,ε2,...,εL)
C7
1≤i≤Z
NB OF SIGNS TO BE HIDDEN (0, 1 OR +)
C71
reduc. Ei=(ε'1,ε'2,...,ε'M),M<L
C72a
SEi
SEi ≤ TSIG ?
Y
N
C72
SEi ≤ TSIG_1<TSIG_2 ?
f(ε'1,ε'2,...,ε'M)
C8
C9
PARITY f = SIGN PARITY ?
N
Y
MODIF. SE i
C10
MODIF. Ei
C11
Ei
Ei-1 SIGN
Emi-1 SIGN
Emi-N SIGNS
ENTROP. COD.
C20
LAST BLOCK ?
C30
C40

Fig. 3

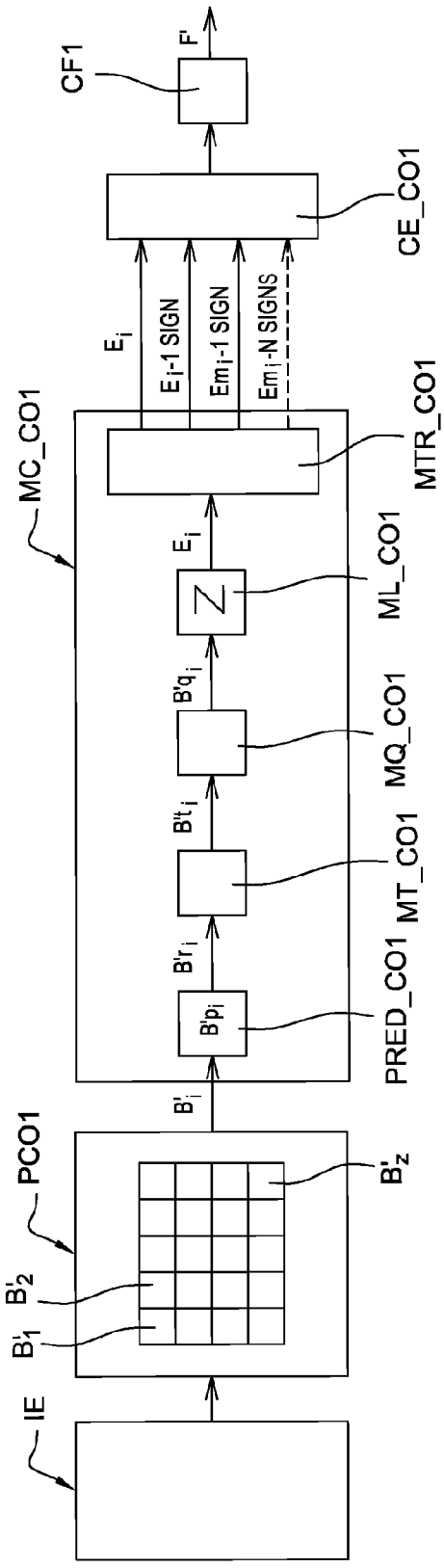

IE
PCO1
B'1
B'2
B'z
B'i
MC_CO1
PRED_CO1
B'pi
B'ri
MT_CO1
B'ti
MQ_CO1
B'qi
ML_CO1
Ei
MTR_CO1
Ei
Ei-1 SIGN
Emi-1 SIGN
Emi-N SIGNS
CE_CO1
CF1
F'
CO1

Fig. 4

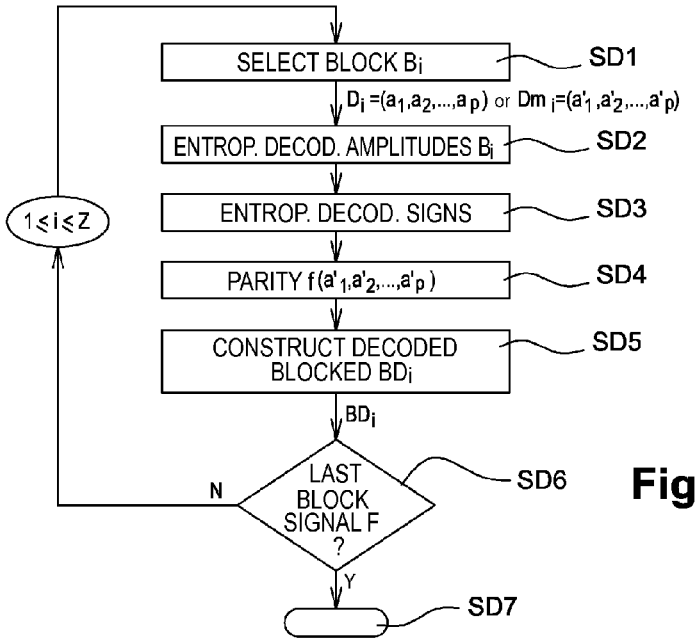

SELECT BLOCK Bi
SD1
Di =(a1,a2,...,ap) or Dm i=(a'1,a'2,...,a'p)
ENTROP. DECOD. AMPLITUDES Bi
SD2
ENTROP. DECOD. SIGNS
SD3
PARITY f(a'1,a'2,...,a'p)
SD4
CONSTRUCT DECODED BLOCKED BDi
SD5
BDi
LAST BLOCK SIGNAL F ?
SD6
N
Y
SD7
1≤i≤Z

Fig. 5

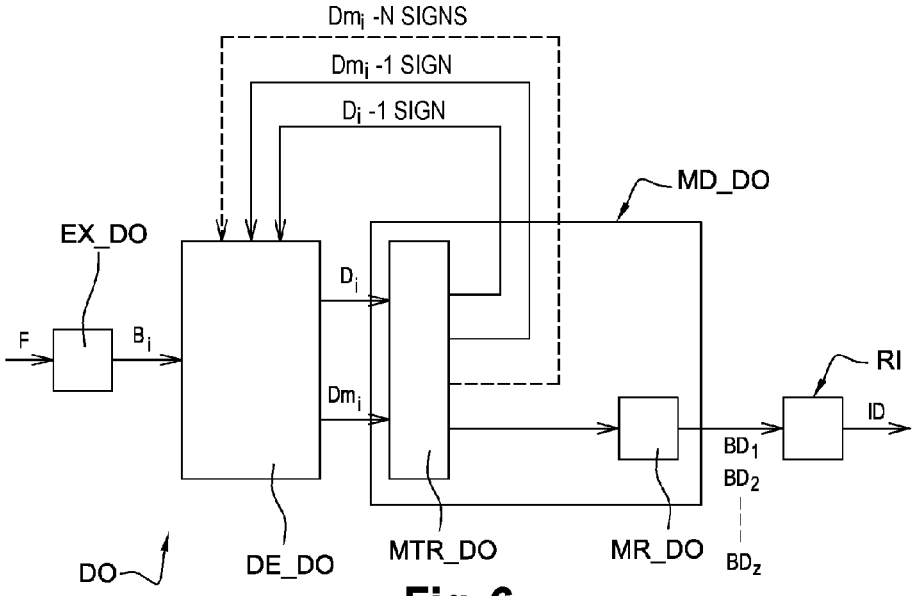

Dmi -N SIGNS
Dmi -1 SIGN
Di -1 SIGN
MD_DO
EX_DO
F
Bi
Di
Dmi
RI
ID
BD1
BD2
BDz
DO
DE_DO
MTR_DO
MR_DO

Fig. 6

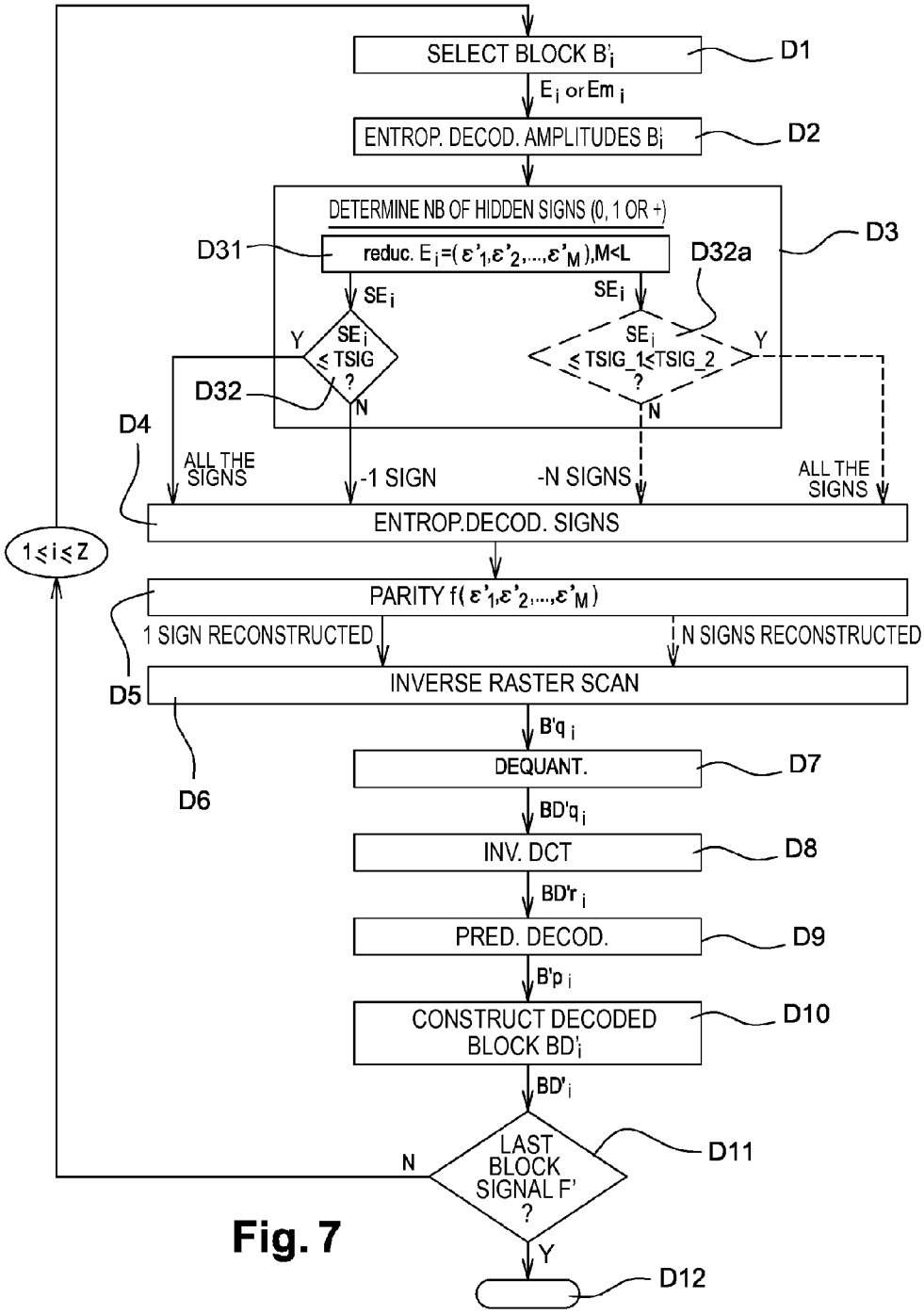

SELECT BLOCK B'i
D1
Ei or Em i
ENTROP. DECOD. AMPLITUDES B'i
D2
DETERMINE NB OF HIDDEN SIGNS (0, 1 OR +)
D3
D31
reduc. Ei=(ε'1,ε'2,...,ε'M),M<L
D32a
SEi
SEi ≤ TSIG ?
Y
N
D32
SEi ≤ TSIG_1<TSIG_2 ?
Y
N
D4
ALL THE SIGNS
-1 SIGN
-N SIGNS
ALL THE SIGNS
ENTROP.DECOD. SIGNS
1≤i≤Z
PARITY f(ε'1,ε'2,...,ε'M)
1 SIGN RECONSTRUCTED
N SIGNS RECONSTRUCTED
D5
INVERSE RASTER SCAN
D6
B'q i
DEQUANT.
D7
BD'q i
INV. DCT
D8
BD'r i
PRED. DECOD.
D9
B'p i
CONSTRUCT DECODED BLOCK BD'i
D10
BD'i
LAST BLOCK SIGNAL F' ?
D11
N
Y
D12

Fig. 7

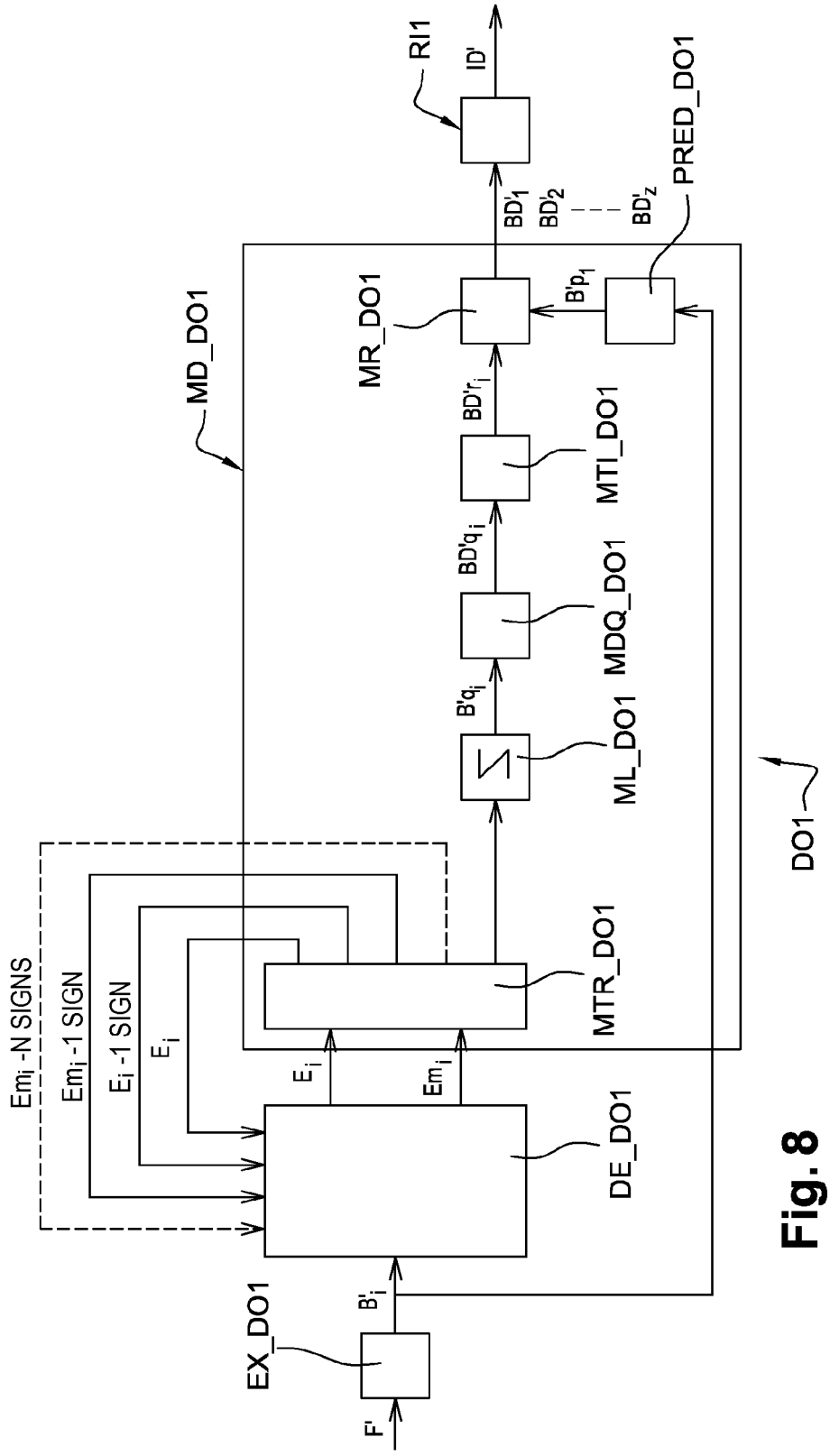

RI1
ID'
PRED_DO1
BD'1
BD'2
BD'z
MD_DO1
MR_DO1
Bp1
BD'ri
MTI_DO1
BD'qi
MDQ_DO1
B'qi
ML_DO1
DO1
MTR_DO1
Emi -N SIGNS
Emi -1 SIGN
Ei -1 SIGN
Ei
Ei
Emi
DE_DO1
EX_DO1
B'i
F'

Fig. 8

CODING AND DECODING IMAGES WITH SIGN DATA HIDING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 14/356,804, filed May 7, 2014, which is a Section 371 National State Application of International Application No. PCT/FR2012/052551, filed Nov. 6, 2012, which is incorporated by reference in its entirety and published as WO 2013/068683 on May 16, 2013, not in English.

FIELD OF THE INVENTION

The present invention pertains generally to the field of the processing of images, and more precisely to the coding and to the decoding of digital images and of sequences of digital images.

The invention can thus, in particular, be applied to the video coding implemented in current video coders (MPEG, H.264, etc.) or forthcoming video coders (ITU-T/VCEG (H.265) or ISO/MPEG (HEVC).

BACKGROUND OF THE INVENTION

Current video coders (MPEG, H.264, etc.) use a block-wise representation of the video sequence. The images are split up into macro-blocks, each macro-block is itself split up into blocks and each block, or macro-block, is coded by intra-image or inter-image prediction. Thus, certain images are coded by spatial prediction (intra prediction), while other images are coded by temporal prediction (inter prediction) with respect to one or more coded-decoded reference images, with the aid of a motion compensation known by the person skilled in the art.

For each block there is coded a residual block, also called prediction residual, corresponding to the original block decreased by a prediction. The residual blocks are transformed by a transform of discrete cosine transform (DCT) type, and then quantized with the aid of a quantization for example of scalar type. Coefficients, some of which are positive and others negative, are obtained on completion of the quantization step. They are thereafter traversed in an order of reading, generally zig-zag (as in the JPEG standard), thereby making it possible to utilize the significant number of zero coefficients in the high frequencies. On completion of the aforementioned traversal, a one-dimensional list of coefficients is obtained, which will be called "quantized residual". The coefficients of this list are then coded by an entropy coding.

The entropy coding (for example of arithmetical coding or Huffman coding type) is performed in the following manner:

- an item of information is coded entropically to indicate the location of the last non-zero coefficient of the list,
- for each coefficient situated before the last non-zero coefficient, an item of information is coded entropically to indicate whether the coefficient is or is not zero,
- for each previously indicated non-zero coefficient, an item of information is coded entropically to indicate whether the coefficient is or is not equal to one,
- for each non-zero coefficient not equal to one situated before the last non-zero coefficient, an amplitude item of information (absolute value of the coefficient decreased by two) is coded entropically,
- for each non-zero coefficient, the sign which is allotted to it is coded by a '0' (for the + sign) or a '1' (for the − sign).

According to the H.264 technique for example, when a macroblock is split up into blocks, a data signal, corresponding to each block, is transmitted to the decoder. Such a signal comprises:

- the quantized residuals contained in the aforementioned list,
- information representative of the mode of coding used, in particular:
  - the mode of prediction (intra prediction, inter prediction, default prediction carrying out a prediction for which no item of information is transmitted to the decoder ("skip"));
  - information specifying the type of prediction (orientation, reference image, etc.);
  - the type of partitioning;
  - the type of transform, for example 4×4 DCT, 8×8 DCT, etc.
  - the motion information if necessary;
  - etc.

The decoding is done image by image, and for each image, macroblock by macroblock. For each partition of a macroblock, the corresponding elements of the stream are read. The inverse quantization and the inverse transformation of the coefficients of the blocks are performed so as to produce the decoded prediction residual. Next, the prediction of the partition is calculated and the partition is reconstructed by adding the prediction to the decoded prediction residual.

The intra or inter coding by competition, such as implemented in the H.264 standard, thus relies on various items of coding information, such as those aforementioned, being set into competition with the aim of selecting the best mode, that is to say that which will optimize the coding of the partition considered according to a predetermined performance criterion, for example the bitrate/distortion cost well known to the person skilled in the art.

The information representative of the mode of coding selected is contained in the data signal transmitted by the coder to the decoder. The decoder is thus capable of identifying the mode of coding selected at the coder, and then of applying the prediction in accordance with this mode.

In the document "Data Hiding of Motion Information in Chroma and Luma Samples for Video Compression", J.-M. Thiesse, J. Jung and M. Antonini, International workshop on multimedia signal processing, 2011, there is presented a data hiding method implemented in the course of video compression.

More precisely, it is proposed to avoid including in the signal to be transmitted to the decoder at least one competition index such as arises from a plurality of competition indices to be transmitted. Such an index is for example the index MVComp which represents an item of information making it possible to identify the motion vector predictor used for a block predicted in Inter mode. Such an index, which can equal 0 or 1, is not inscribed directly into the coded data signal, but transported by the parity of the sum of the coefficients of the quantized residual. An association is created between the parity of the quantized residual and the index MVComp. By way of example, the even value of the quantized residual is associated with the index MVComp of value 0, while the odd value of the quantized residual is associated with the index MVComp of value 1. Two cases can occur. In a first case, if the parity of the quantized residual already corresponds to that of the index MVComp that it is desired to transmit, the quantized residual is coded in a conventional manner. In a second case, if the parity of the quantized residual is different from that of the index MVComp that it is desired to transmit, there is undertaken a modification of

the quantized residual in such a way that its parity is the same as that of the index MVComp. Such a modification consists in incrementing or decrementing one or more coefficients of the quantized residual by an odd value (e.g.: +1, −1, +3, −3, +5, −5, etc.) and to retain only the modification which optimizes a predetermined criterion, in this instance the aforementioned bitrate-distortion cost.

At the decoder, the index MVComp is not read from the signal. The decoder simply makes do with determining the residual conventionally. If the value of this residual is even, the index MVComp is set to 0. If the value of this residual is odd, the index MVComp is set to 1.

In accordance with the technique which has just been presented, the coefficients which undergo the modification are not always chosen in an optimal manner, so that the modification applied gives rise to disturbances in the signal transmitted to the decoder. Such disturbances are inevitably detrimental to the effectiveness of the video compression.

Moreover, the index MVComp does not constitute the most beneficial item of information to be hidden since the probabilities that this index is equal to 0 or to 1 are not equal. Consequently, if this index is coded in a conventional manner by entropy coding, it will be represented, in the compressed file to be transmitted to the decoder, by a smaller quantity of data than one bit per index MVComp transmitted. Consequently, if the index MVComp is transmitted in the parity of the quantized residual, the quantity of data thus saved is smaller than one bit per index MVComp, whereas the parity of the residual could make it possible to transport an item of information of one bit per index.

Consequently, the reduction in the signaling cost, as well as the effectiveness of the compression, are not optimal.

SUMMARY OF THE INVENTION

An embodiment of the present invention relates to a method for coding at least one image split up into partitions, a current partition to be coded containing data at least one data item of which is allotted a sign.

The method according to the invention is noteworthy in that it implements, for the aforementioned current partition, the following steps:

- calculation of the value of a function representative of the data of said current partition with the exclusion of the sign,
- comparison of the calculated value with a predetermined value of the sign,
- as a function of the result of the comparison, modification or otherwise of at least one of the data of the current partition,
- in the case of modification, coding of the at least one modified data item.

Such an arrangement makes it possible advantageously to apply the data hiding technique to the signs of the data of a partition to be coded. A sign is indeed an item of information that it is particularly relevant to hide because of the fact that the probability of appearance of a positive or negative sign is equiprobable. Therefore, given that a sign is necessarily coded on a bit, it is thus possible, by hiding this item of information, to make a saving of one bit in the signal to be transmitted to the decoder, thereby substantially reducing the signaling cost.

It should be noted that among the information (sign, amplitude, etc.) associated with an image data item, very few of them are equiprobable. The sign being an equiprobable item of information, there is therefore a specific benefit in hiding an item of information of this type, thereby making it possible to increase the compression performance.

In a particular embodiment, in the case where a plurality of signs is considered in the course of the aforementioned comparison step, the latter consists in comparing the calculated value of a function representative of the data of the current partition with the value of a function representative of the plurality of signs.

Such an arrangement makes it possible to optimize the compression performance of the arithmetical coder while optimizing the reduction in the signaling cost, since it makes it possible to hide several signs in the signal to be transmitted to the decoder.

Correlatively, the invention relates to a device for coding at least one image split up into partitions, a current partition to be coded containing data at least one data item of which is allotted a sign.

Such a coding device is noteworthy in that it comprises processing means which, for the current partition to be coded, are able to:

- calculate the value of a function representative of the data of the current partition with the exclusion of the sign,
- compare the calculated value with a predetermined value of the sign,
- modify or otherwise at least one of the data of the current partition as a function of the result of the comparison,

and in that it comprises means for coding the at least one modified data item, in the case of modification by the processing means.

In a corresponding manner, the invention also relates to a method for decoding a data signal representative of at least one image split up into partitions which has been previously coded, a current partition to be decoded containing data at least one data item of which is allotted a sign.

Such a decoding method is noteworthy in that it comprises, for the current partition, the following steps:

- decoding of the data of the current partition, with the exclusion of the sign,
- calculation of the value of a function representative of the decoded data of the current partition,
- obtaining, on the basis of the calculated value, of the value of the sign.

In a particular embodiment, a plurality of values associated respectively with a plurality of signs is obtained on the basis of the calculated value.

Correlatively, the invention relates to a device for decoding a data signal representative of at least one image split up into partitions which has been previously coded, a current partition to be decoded containing data at least one data item of which is allotted a sign.

Such a decoding device is noteworthy in that it comprises processing means which, for the current partition to be decoded, are able to:

- decode the data of the current partition, with the exclusion of the sign,
- calculate the value of a function representative of the decoded data of the current partition,
- obtain, on the basis of the calculated value, the value of the sign.

The invention is also aimed at a computer program comprising instructions for the execution of the steps of the coding or decoding method hereinabove, when the program is executed by a computer.

Such a program can use any programming language, and be in the form of source code, object code, or of code intermediate between source code and object code, such as in a partially compiled form, or in any other desirable form.

Yet another subject of the invention is also aimed at a recording medium readable by a computer, and comprising instructions for computer program such as mentioned hereinabove.

The recording medium can be any entity or device capable of storing the program. For example, such a medium can comprise a storage means, such as a ROM, for example a CD ROM or a microelectronic circuit ROM, or else a magnetic recording means, for example a diskette (floppy disk) or a hard disk.

Moreover, such a recording medium can be a transmissible medium such as an electrical or optical signal, which can be conveyed via an electrical or optical cable, by radio or by other means. The program according to the invention can be in particular downloaded from a network of Internet type.

Alternatively, such a recording medium can be an integrated circuit into which the program is incorporated, the circuit being adapted to execute the method in question or to be used in the execution of the latter.

The coding device, the decoding method, the decoding device and the aforementioned computer programs exhibit at least the same advantages as those conferred by the coding method according to the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Other characteristics and advantages will become apparent on reading two preferred embodiments described with reference to the figures in which:

FIG. **1** represents the general steps of the coding method according to the invention,

FIG. **2** represents a coding device according to the invention which is able to perform the steps of the coding method of FIG. **1**,

FIG. **3** represents a particular embodiment of the coding method according to the invention,

FIG. **4** represents a particular embodiment of a coding device according to the invention,

FIG. **5** represents the general steps of the decoding method according to the invention,

FIG. **6** represents a decoding device according to the invention which is able to perform the steps of the decoding method of FIG. **5**,

FIG. **7** represents a particular embodiment of the decoding method according to the invention,

FIG. **8** represents a particular embodiment of a decoding device according to the invention.

DETAILED DESCRIPTION OF THE CODING PART

A general embodiment of the invention will now be described, in which the coding method according to the invention is used to code a sequence of images according to a binary stream close to that which is obtained by a coding according to the H.264/MPEG-4 AVC standard. In this embodiment, the coding method according to the invention is for example implemented in a software or hardware manner by modifications of a coder initially complying with the H.264/MPEG-4 AVC standard.

The coding method according to the invention is represented in the form of an algorithm comprising steps **S1** to **S40**, represented in FIG. **1**.

According to the embodiment of the invention, the coding method according to the invention is implemented in a coding device or coder CO of which an embodiment is represented in FIG. **2**.

In accordance with the invention, there is undertaken, prior to the coding proper, a splitting of an image IE of a sequence of images to be coded in a predetermined order, into a plurality Z of partitions $B_1, B_2, \ldots, B_i, \ldots, B_Z$, as represented in FIG. **2**.

It should be noted that, within the meaning of the invention, the term "partition" signifies coding unit. The latter terminology is in particular used in the HEVC/H.265 standard currently being formulated, for example in the document accessible at the following Internet address: http://phenix.intevry.fr/jct/doc end user/current document.php?id=3286.

In particular, such a coding unit groups together sets of pixels of rectangular or square shape, also called blocks, macroblocks, or else sets of pixels exhibiting other geometric shapes.

In the example represented in FIG. **2**, said partitions are blocks which have a square shape and all have the same size. As a function of the size of the image which is not necessarily a multiple of the size of the blocks, the last blocks on the left and the last blocks at the bottom might not be square. In an alternative embodiment, the blocks may be for example of rectangular size and/or not aligned one with another.

Each block or macroblock may moreover itself be divided into sub-blocks which are themselves subdividable.

Such a splitting is performed by a partitioning module PCO represented in FIG. **2** which uses for example a partitioning algorithm well known as such.

Subsequent to said splitting step, there is undertaken the coding of each of the current partitions B_i (i being an integer such that $1 \leq i \leq Z$) of said image IE.

In the example represented in FIG. **2**, such a coding is applied successively to each of the blocks B_1 to B_Z of the current image IE. The blocks are coded according to for example a traversal such as the "raster scan" traversal well known to the person skilled in the art.

The coding according to the invention is implemented in a coding software module MC_CO of the coder CO, such as represented in FIG. **2**.

In the course of a step **S1** represented in FIG. **1**, the coding module MC_CO of FIG. **2** selects as current block B_i the first block B_1 to be coded of the current image IE. As represented in FIG. **2**, this is the first left block of the image IE.

In the course of a step **S2** represented in FIG. **1**, there is undertaken the extraction of data of the current block B_1 in the form of a list $D_1=(a_1, a_2, \ldots, a_P)$. Such an extraction is performed by a software module EX_CO such as represented in FIG. **2**. Such data are for example pixel data, the non-zero pixel data each being allotted either with a positive sign, or with a negative sign.

Each of the data of the list D_1 is associated with various items of digital information which are intended to undergo an entropy coding. Items of digital information such as these are described hereinbelow by way of example:

- for each data item situated before the last non-zero data item of the list D_1, a digital item of information, such as a bit, is intended to be coded entropically to indicate whether the data item is or is not zero: if the data item is zero, it is for example the bit of value 0 which will be coded, while if the data item is non-zero, it is the bit of value 1 which will be coded;
- for each non-zero data item, a digital item of information, such as a bit, is intended to be coded entropically to indicate whether the absolute value of the data item is or is not equal to one: if it is equal to 1, it is for example the bit of value 1 which will be coded, while if it is not equal to 1, it is the bit of value 0 which will be coded;

for each non-zero data item whose absolute value is not equal to one and which is situated before the last non-zero data item, an amplitude item of information is coded entropically,

for each non-zero data item, the sign which is allotted to it is coded by a digital item of information, such as a bit for example set to '0' (for the + sign) or to '1' (for the − sign).

The specific coding steps according to the invention will now be described with reference to FIG. **1**.

In accordance with the invention, it is decided to avoid entropically coding at least one sign of one of said data of the list D_1.

In accordance with the preferred embodiment, it is the sign of the first non-zero data item which is intended to be hidden. Such a sign is for example positive and allotted to the first non-zero data item, such as for example the data item a_2.

In the course of a step **S3** represented in FIG. **1**, the processing module MTR_CO calculates the value of a function f which is representative of the data of the list D_1.

In the preferred embodiment where a single sign is intended to be hidden in the signal to be transmitted to the decoder, the function f is the parity of the sum of the data of the list D_1.

In the course of a step **S4** represented in FIG. **1**, the processing module MTR_CO verifies whether the parity of the value of the sign to be hidden corresponds to the parity of the sum of the data of the list D_1, by virtue of a convention defined previously at the coder CO.

In the example proposed, said convention is such that a positive sign is associated with a bit of value equal to zero, while a negative sign is associated with a bit of value equal to one.

If, in accordance with the convention adopted in the coder CO according to the invention, the sign is positive, thereby corresponding to a zero coding bit value, and if the sum of the data of the list D_1 is even, there is undertaken a step **S20** of entropy coding of the data of the aforementioned list D_1, with the exception of the sign of the first non-zero data item a_2. Such a step **S20** is represented in FIG. **1**.

If, still in accordance with the convention adopted in the coder CO according to the invention, the sign is negative, thereby corresponding to a one coding bit value, and if the sum of the data of the list D_1 is odd, there is also undertaken the step **S20** of entropy coding of the data of the aforementioned list D_1, with the exception of the sign of the first non-zero data item a_2.

If, in accordance with the convention adopted in the coder CO according to the invention, the sign is positive, thereby corresponding to a zero coding bit value, and if the sum of the data of the list D_1 is odd, there is undertaken, in the course of a step **S5** represented in FIG. **1**, a modification of at least one modifiable data item of the list D_1.

If, still in accordance with the convention adopted in the coder CO according to the invention, the sign is negative, thereby corresponding to a one coding bit value, and if the sum of the data of the list D_1 is even, there is also undertaken step **S5** of modifying at least one modifiable data item of the list D_1.

According to the invention, a data item is modifiable if the modification of its value does not cause any desynchronization at the decoder, once this modified data item is processed by the decoder. Thus, the processing module MTR_CO is configured initially so as not to modify:

the zero data item or data situated before the first non-zero data item, in such a way that the decoder does not allot the value of the hidden sign to this or these zero data.

and for calculation complexity reasons, the zero data item or data situated after the last non-zero data item.

Such a modification operation is performed by the processing module MTR_CO of FIG. **2**.

In the proposed exemplary embodiment, it is assumed that the total sum of the data of the list D_1 is equal to 5, and is therefore odd. So that the decoder can reconstruct the positive sign allotted to the first non-zero data item a_2, without the coder CO having to transmit this data item to the decoder, it is necessary that the parity of the sum become even. Consequently, the processing module MTR_CO tests, in the course of said step **S5**, various modifications of data of the list D_1, all aimed at changing the parity of the sum of the data. In the preferred embodiment, there is undertaken the addition of +1 or −1 to each modifiable data item and the selection, according to a predetermined criterion, of a modification from among all those performed.

A modified list $Dm_1=(a'_1, a'_2, \ldots, a'_P)$ is then obtained, on completion of step **S5**.

It should be noted that, in the course of this step, certain modifications are prohibited. Thus, in the case where the first non-zero data item equals+1, it would not be possible to add−1 to it, since it would become zero, and it would then lose its characteristic of first non-zero data item of the list D_1. The decoder would then subsequently allocate the decoded sign (by calculation of the parity of the sum of the data) to another data item, and there would then be a decoding error.

There is thereafter undertaken step **S20** of entropy coding of the data of the aforementioned list Dm_1, with the exception of the positive sign of the first non-zero data item a_2, which sign is hidden in the parity of the sum of the data.

It should be noted that the set of amplitudes of the data of the list D_1 or of the modified list Dm_1 is coded before the set of signs, with the exclusion of the sign of the first non-zero data item which is not coded, as was explained hereinabove.

In the course of a following step **S30** represented in FIG. **1**, the coding module MC_CO of FIG. **2** tests whether the coded current block is the last block of the image IE.

If the current block is the last block of the image IE, in the course of a step **S40** represented in FIG. **1**, the coding method is terminated.

If such is not the case, there is undertaken the selection of the following block B_i which is then coded in accordance with the aforementioned raster scan order of traversal, by iteration of steps **S1** to **S20**, for $1 \leq i \leq Z$.

Once the entropy coding of all the blocks B_1 to B_Z has been carried out, there is undertaken the construction of a signal F representing, in binary form, said coded blocks.

The construction of the binary signal F is implemented in a stream construction software module CF, such as represented in FIG. **2**.

The stream F is thereafter transmitted by a communication network (not represented), to a remote terminal. The latter comprises a decoder which will be described in greater detail in the subsequent description.

Another embodiment of the invention will now be described, mainly with reference to FIG. **1**.

This other embodiment is distinguished from the previous one solely by the number of signs to be hidden which is N, N being an integer such that $N \geq 2$.

For this purpose, the function f is the remainder modulo 2^N of the sum of the data of the list D_1. It is assumed that in the example proposed, N=2, the two signs to be hidden are the first two signs of the first two non-zero data of the list D_1, for example a_2 and a_3.

In the course of step **S4** represented in FIG. **1**, the processing module MTR_CO verifies whether the configuration of

the N signs, i.e. 2^N possible configurations, corresponds to the value of the remainder modulo 2^N of the sum of the data of the list D_1.

In the example proposed where N=2, there exist 2^2=4 different configurations of signs.

These four configurations obey a convention at the coder CO, which is for example determined in the following manner:

- a remainder equal to zero corresponds to two consecutive positive signs: +, +;
- a remainder equal to one corresponds to a consecutive positive sign and negative sign: +, −;
- a remainder equal to two corresponds to a consecutive negative sign and positive sign: −, +;
- a remainder equal to three corresponds to two consecutive negative signs: −, −.

If the configuration of the N signs corresponds to the value of the remainder modulo 2^N of the sum of the data of the list D_1, there is undertaken step S**20** of entropy coding of the data of the aforementioned list D_1, with the exception of the respective sign of the first two non-zero data a_2 and a_3, which signs are hidden in the parity of the sum modulo 2^N of the data of the list D_1.

If such is not the case, there is undertaken step S**5** of modifying at least one modifiable data item of the list D_1. Such a modification is performed by the processing module MTR_CO of FIG. **2** in such a way that the remainder modulo 2^N of the sum of the modifiable data of the list D_1 attains the value of each of the two signs to be hidden.

A modified list $Dm_1=(a'_1, a'_2, \ldots, a'_P)$ is then obtained.

There is thereafter undertaken step S**20** of entropy coding of the data of the aforementioned list Dm_1, with the exception of the sign of the first non-zero data item a_2 and of the sign of the second non-zero data item a_3, which signs are hidden in the parity of the sum modulo 2^N of the data.

A particular embodiment of the invention will now be described, in which the coding method according to the invention is still used to code a sequence of images according to a binary stream close to that which is obtained by a coding according to the H.264/MPEG-4 AVC standard. In this embodiment, the coding method according to the invention is for example implemented in a software or hardware manner by modifications of a coder initially complying with the H.264/MPEG-4 AVC standard.

The coding method according to the invention is represented in the form of an algorithm comprising steps C**1** to C**40**, such as represented in FIG. **3**.

According to the embodiment of the invention, the coding method is implemented in a coding device or coder CO**1** of which an embodiment is represented in FIG. **4**.

In accordance with the invention, and as described in the previous examples, there is undertaken, prior to the coding proper, a splitting of an image IE of a sequence of images to be coded in a predetermined order, into a plurality Z of partitions $B'_1, B'_2, \ldots, B'_i, \ldots, B'_Z$, as represented in FIG. **4**.

In the example represented in FIG. **4**, said partitions are blocks which have a square shape and all have the same size. As a function of the size of the image which is not necessarily a multiple of the size of the blocks, the last blocks on the left and the last blocks at the bottom might not be square. In an alternative embodiment, the blocks may be for example of rectangular size and/or not aligned one with another.

Each block or macroblock may moreover itself be divided into sub-blocks which are themselves subdividable.

Such a splitting is performed by a partitioning software module PCO**1** represented in FIG. **4** which is identical to the partitioning module PCO represented in FIG. **2**.

Subsequent to said splitting step, there is undertaken the coding of each of the current partitions B'_i (i being an integer such that $1 \leq i \leq Z$) of said image IE.

In the example represented in FIG. **4**, such a coding is applied successively to each of the blocks B'_1 to B'_Z of the current image IE. The blocks are coded according to a traversal such as for example the "raster scan" traversal well known to the person skilled in the art.

The coding according to the invention is implemented in a coding software module MC_CO**1** of the coder CO**1**, such as represented in FIG. **4**.

In the course of a step C**1** represented in FIG. **3**, the coding module MC_CO**1** of FIG. **4** selects as current block B'_i the first block B'_1 to be coded of the current image IE. As represented in FIG. **4**, this is the first left block of the image IE.

In the course of a step C**2** represented in FIG. **3**, there is undertaken the predictive coding of the current block B'_1 by known techniques of intra and/or inter prediction, in the course of which the block B'_1 is predicted with respect to at least one previously coded and decoded block. Such a prediction is performed by a prediction software module PRED_CO**1** such as represented in FIG. **4**.

It goes without saying that other modes of intra prediction, such as are proposed in the H.264 standard, are possible.

The current block B'_1 can also be subjected to a predictive coding in inter mode, in the course of which the current block is predicted with respect to a block arising from a previously coded and decoded image. Other types of prediction are of course conceivable. Among the possible predictions for a current block, the optimal prediction is chosen according to a rate distortion criterion well known to the person skilled in the art.

Said aforementioned predictive coding step makes it possible to construct a predicted block $B'p_1$ which is an approximation of the current block B'_1. The information relating to this predictive coding is intended to be inscribed in a signal to be transmitted to the decoder. Such information comprises in particular the type of prediction (inter or intra) and, if appropriate, the mode of intra prediction, the type of partitioning of a block or macroblock if the latter has been subdivided, the reference image index and the displacement vector used in the mode of inter prediction. This information is compressed by the coder CO**1**.

In the course of a following step C**3** represented in FIG. **3**, the prediction module PRED_CO**1** compares the data relating to the current block B'_1 with the data of the predicted block $B'p_1$. More precisely, in the course of this step, there is undertaken conventionally the subtraction of the predicted block $B'p_1$ from the current block B'_1 to produce a residual block $B'r_1$.

In the course of a following step C**4** represented in FIG. **3**, there is undertaken the transformation of the residual block $B'r_1$, according to a conventional direct transformation operation, such as for example a discrete cosine transformation DCT, to produce a transformed block $B't_1$. Such an operation is performed by a transform software module MT_CO**1**, such as represented in FIG. **4**.

In the course of a following step C**5** represented in FIG. **3**, there is undertaken the quantization of the transformed block $B't_1$, according to a conventional quantization operation, such as for example a scalar quantization. A block $B'q_1$ of quantized coefficients is then obtained. Such a step is performed by means of a quantization software module MQ_CO**1**, such as represented in FIG. **4**.

In the course of a following step C**6** represented in FIG. **3**, there is undertaken a traversal, in a predefined order, of the quantized coefficients of the block $B'q_1$. In the example rep-

resented this entails a conventional zig-zag traversal. Such a step is performed by a reading software module ML_CO1, such as represented in FIG. **4**. On completion of step C**6**, a one-dimensional list E_1=(ϵ1, ϵ2, . . . , ϵL) of coefficients is obtained, better known by the term "quantized residual", where L is an integer greater than or equal to 1. Each of the coefficients of the list E_1 is associated with various items of digital information which are intended to undergo an entropy coding. Such items of digital information are described hereinbelow by way of example.

Let us assume that, in the example represented, L=16 and that the list E_1 contains the following sixteen coefficients: E_1=(0, +9, −7, 0, 0, +1, 0, −1, +2, 0, 0, +1, 0, 0, 0, 0).

In this instance:

- for each coefficient situated before the last non-zero coefficient of the list E_1, a digital item of information, such as a bit, is intended to be coded entropically to indicate whether the coefficient is or is not zero: if the coefficient is zero, it is for example the bit of value 0 which will be coded, while if the coefficient is non-zero, it is the bit of value 1 which will be coded;
- for each non-zero coefficient+9, −7, +1, −1, +2, +1, a digital item of information, such as a bit, is intended to be coded entropically to indicate whether the absolute value of the coefficient is or is not equal to one: if it is equal to 1, it is for example the bit of value 1 which will be coded, while if it is not equal to 1, it is the bit of value 0 which will be coded;
- for each non-zero coefficient whose absolute value is not equal to one and situated before the last non-zero coefficient, such as the coefficients of value+9, −7, +2, an amplitude item of information (absolute value of the coefficient from which the value two is deducted) is coded entropically,
- for each non-zero coefficient, the sign which is allotted to it is coded by a digital item of information, such as a bit for example set to '0' (for the + sign) or to '1' (for the − sign).

The specific coding steps according to the invention will now be described with reference to FIG. **3**.

In accordance with the invention, it is decided to avoid entropically coding at least one of the aforementioned items of digital information, which is at least one sign of one of said coefficients of the list E_1.

For this purpose, in the course of a step C**7** represented in FIG. **3**, there is undertaken the choice of the number of signs to be hidden in the course of the subsequent entropy coding step. Such a step is performed by a processing software module MTR_CO**1**, such as represented in FIG. **4**.

In the preferred embodiment, the number of signs to be hidden is one or zero. Furthermore, in accordance with said preferred embodiment, it is the sign of the first non-zero coefficient which is intended to be hidden. In the example represented, this therefore entails hiding the sign of the coefficient ϵ2=+9.

In an alternative embodiment, the number of signs to be hidden is either zero, or one, or two, or three, or more.

In accordance with the preferred embodiment of step C**7**, there is undertaken, in the course of a first sub-step C**71** represented in FIG. **3**, the determination, on the basis of said list E_1, of a sub-list SE_1 containing coefficients able to be modified ϵ'1, ϵ'2, . . . , ϵ'M where M<L. Such coefficients will be called modifiable coefficients in the subsequent description.

According to the invention, a coefficient is modifiable if the modification of its quantized value does not cause any desynchronization at the decoder, once this modified coefficient is processed by the decoder. Thus, the processing module MTR_CO**1** is configured initially so as not to modify:

- the zero coefficient or coefficients situated before the first non-zero coefficient, in such a way that the decoder does not allot the value of the hidden sign to this or these zero coefficients,
- and for calculation complexity reasons, the zero coefficient or coefficients situated after the last non-zero coefficient.

In the example represented, on completion of sub-step C**71**, the sub-list SE_1 obtained is such that SE_1=(9,−7,0,0,1, 0,−1,2,0,0,1). Consequently, eleven modifiable coefficients are obtained.

In the course of a following sub-step C**72** represented in FIG. **3**, the processing module MTR_CO**1** undertakes the comparison of the number of modifiable coefficients with a predetermined threshold TSIG. In the preferred embodiment, TSIG equals 4.

If the number of modifiable coefficients is less than the threshold TSIG, there is undertaken, in the course of a step C**20** represented in FIG. **3**, a conventional entropy coding of the coefficients of the list E_1, such as that carried out for example in a CABAC coder, designated by the reference CE_CO**1** in FIG. **4**. For this purpose, the sign of each non-zero coefficient of the list E_1 is coded entropically.

If the number of modifiable coefficients is greater than the threshold TSIG, in the course of a step C**8** represented in FIG. **3**, the processing module MTR_CO**1** calculates the value of a function f which is representative of the coefficients of the sub-list SE_1.

In the preferred embodiment where a single sign is intended to be hidden in the signal to be transmitted to the decoder, the function f is the parity of the sum of the coefficients of the sub-list SE_1.

In the course of a step C**9** represented in FIG. **3**, the processing module MTR_CO**1** verifies whether the parity of the value of the sign to be hidden corresponds to the parity of the sum of the coefficients of the sub-list SE_1, by virtue of a convention defined previously at the coder CO**1**.

In the example proposed, said convention is such that a positive sign is associated with a bit of value equal to zero, while a negative sign is associated with a bit of value equal to one.

If, in accordance with the convention adopted in the coder CO**1** according to the invention, the sign is positive, thereby corresponding to a zero coding bit value, and if the sum of the coefficients of the sub-list SE_1 is even, there is undertaken the step C**20** of entropy coding of the coefficients of the aforementioned list E_1, with the exception of the sign of the coefficient ϵ2.

If, still in accordance with the convention adopted in the coder CO**1** according to the invention, the sign is negative, thereby corresponding to a one coding bit value, and if the sum of the coefficients of the sub-list SE_1 is odd, there is also undertaken the step C**20** of entropy coding of the coefficients of the aforementioned list E_1, with the exception of the sign of the coefficient ϵ2.

If, in accordance with the convention adopted in the coder CO**1** according to the invention, the sign is positive, thereby corresponding to a zero coding bit value, and if the sum of the coefficients of the sub-list SE_1 is odd, there is undertaken, in the course of a step C**10** represented in FIG. **3**, a modification of at least one modifiable coefficient of the sub-list SE_1.

If, still in accordance with the convention adopted in the coder CO**1** according to the invention, the sign is negative, thereby corresponding to a one coding bit value, and if the

sum of the coefficients of the sub-list SE_1 is even, there is also undertaken step C**10** of modifying at least one modifiable coefficient of the sub-list SE_1.

Such a modification operation is performed by the processing module MTR_CO**1** of FIG. **4**.

In the exemplary embodiment where SE_1=(+9,−7,0,0,+1, 0,−1,+2,0,0,+1), the total sum of the coefficient is equal to 5, and is therefore odd. So that the decoder can reconstruct the positive sign allotted to the first non-zero coefficient, $\epsilon 2$=+9, without the coder CO**1** having to transmit this coefficient to the decoder, the parity of the sum must become even. Consequently, the processing module MTR_CO**1** tests, in the course of said step C**10**, various modifications of coefficients of the sub-list SE_1, all aimed at changing the parity of the sum of the coefficients. In the preferred embodiment, there is undertaken the addition of +1 or −1 to each modifiable coefficient and the selection of a modification from among all those performed.

In the preferred embodiment, such a selection constitutes the optimal prediction according to a performance criterion which is for example the bitrate distortion criterion well known to the person skilled in the art. Such a criterion is expressed by equation (1) hereinbelow:

$$J=D+\lambda R \quad (1)$$

where

D represents the distortion between the original macroblock and the reconstructed macroblock, R represents the cost in bits of the coding of the coding information and λ represents a Lagrange multiplier, the value of which can be fixed prior to the coding.

In the example proposed, the modification which gives rise to an optimal prediction according to the aforementioned bitrate-distortion criterion is the addition of the value 1 to the second coefficient−7 of the sub-list SE_1.

A modified sub-list SEm_1=(+9,−6,0,0,+1,0,−1,+2,0,0,+1) is then obtained on completion of step C**10**.

It should be noted that in the course of this step, certain modifications are prohibited. Thus, in the case where the first non-zero coefficient $\epsilon 2$ would have been equal to +1, it would not have been possible to add−1 to it, since it would have become zero, and it would then have lost its characteristic of first non-zero coefficient of the list E_1. The decoder would then have subsequently allocated the decoded sign (by calculation of the parity of the sum of the coefficients) to another coefficient, and there would then have been a decoding error.

In the course of a step C**11** represented in FIG. **3**, the processing module MTR_CO**1** undertakes a corresponding modification of the list E_1. The following modified list Em_1= (0,+9,−6,0,0,+1,0,−1,+2,0,0,+1,0,0,0,0) is then obtained.

There is thereafter undertaken the step C**20** of entropy coding of the coefficients of the aforementioned list Em_1, with the exception of the sign of the coefficient $\epsilon 2$, which is the + sign of the coefficient 9 in the example proposed, which sign is hidden in the parity of the sum of the coefficients.

It should be noted that the set of amplitudes of the coefficients of the list E_1 or of the modified list Em_1 is coded before the set of signs, with the exclusion of the sign of the first non-zero coefficient $\epsilon 2$ which is not coded, as has been explained hereinabove.

In the course of a following step C**30** represented in FIG. **3**, the coding module MC_CO**1** of FIG. **4** tests whether the coded current block is the last block of the image IE.

If the current block is the last block of the image IE, in the course of a step C**40** represented in FIG. **3**, the coding method is terminated.

If such is not the case, there is undertaken the selection of the block following B'_1 which is then coded in accordance with the aforementioned raster scan order of traversal, by iteration of steps C**1** to C**20**, for $1 \leq i \leq Z$.

Once the entropy coding of all the blocks B'_1 to B'_Z has been carried out, there is undertaken the construction of a signal F' representing, in binary form, said coded blocks.

The construction of the binary signal F' is implemented in a stream construction software module CF**1**, such as represented in FIG. **4**.

The stream F' is thereafter transmitted by a communication network (not represented), to a remote terminal. The latter comprises a decoder which will be described in greater detail in the subsequent description.

Another embodiment of the invention will now be described, mainly with reference to FIG. **3**.

This other embodiment is distinguished from the previous one solely by the number of coefficients to be hidden which is either 0, or N, N being an integer such that N≥2.

For this purpose, the aforementioned comparison sub-step C**72** is replaced with sub-step C**72***a* represented dashed in FIG. **3**, in the course of which there is undertaken the comparison of the number of modifiable coefficients with several predetermined thresholds 0<TSIG_1<TSIG_2<TSIG_3 . . . , in such a way that if the number of modifiable coefficients lies between TSIG_N and TSIG_N+1, N signs are intended to be hidden.

If the number of modifiable coefficients is less than the first threshold TSIG_1, there is undertaken, in the course of the aforementioned step C**20**, the conventional entropy coding of the coefficients of the list E_1. For this purpose, the sign of each non-zero coefficient of the list E_1 is coded entropically.

If the number of modifiable coefficients lies between the threshold TSIG_N and TSIG_N+1, in the course of a step C**8** represented in FIG. **3**, the processing module MTR_CO**1** calculates the value of a function f which is representative of the coefficients of the sub-list SE_1.

In this other embodiment, the decision at the coder being to hide N signs, the function f is the remainder modulo 2^N of the sum of the coefficients of the sub-list SE_1. It is assumed that in the example proposed, N=2, the two signs to be hidden are the first two signs of the first two non-zero coefficients respectively, namely $\epsilon 2$ and $\epsilon 3$.

In the course of the following step C**9** represented in FIG. **3**, the processing module MTR_CO**1** verifies whether the configuration of the N signs, i.e. 2^N possible configurations, corresponds to the value of the remainder modulo 2^N of the sum of the coefficients of the sub-list SE_1.

In the example proposed where N=2, there exist 2^2=4 different configurations of signs.

These four configurations obey a convention at the coder CO**1**, which is for example determined in the following manner:

- a remainder equal to zero corresponds to two consecutive positive signs: +, +;
- a remainder equal to one corresponds to a consecutive positive sign and negative sign: +, −;
- a remainder equal to two corresponds to a consecutive negative sign and positive sign: −, +;
- a remainder equal to three corresponds to two consecutive negative signs: −, −.

If the configuration of the N signs corresponds to the value of the remainder modulo 2^N of the sum of the coefficients of the sub-list SE_1, there is undertaken the step C**20** of entropy coding of the coefficients of the aforementioned list E_1, with

the exception of the sign of the coefficient ϵ2 and of the coefficient ϵ3, which signs are hidden in the parity of the sum modulo 2^N of the coefficients.

If such is not the case, there is undertaken step C**10** of modifying at least one modifiable coefficient of the sub-list SE_1. Such a modification is performed by the processing module MTR_CO**1** of FIG. **4**, in such a way that the remainder modulo 2^N of the sum of the modifiable coefficients of the sub-list SE_1 attains the value of each of the two signs to be hidden.

In the course of the aforementioned step C**11**, the processing module MTR_CO**1** undertakes a corresponding modification of the list E_1. A modified list Em_1 is then obtained.

There is thereafter undertaken step C**20** of entropy coding of the coefficients of the aforementioned list Em_1, with the exception of the sign of the coefficient ϵ2 and of the sign of the coefficient ϵ3, which signs are hidden in the parity of the sum modulo 2^N of the coefficients.

Detailed Description of the Decoding Part

A general embodiment of the decoding method according to the invention will now be described, in which the decoding method is implemented in a software or hardware manner by modifications of a decoder initially complying with the H.264/MPEG-4 AVC standard.

The decoding method according to the invention is represented in the form of an algorithm comprising steps SD**1** to SD**7** represented in FIG. **5**.

According to the general embodiment of the invention, the decoding method according to the invention is implemented in a decoding device or decoder DO, such as represented in FIG. **6**, which is suitable for receiving the stream F delivered by the coder CO of FIG. **2**.

In the course of a preliminary step, not represented in FIG. **5**, there is undertaken the identification, in the data signal F received, of the partitions B_1 to B_Z which have been coded previously by the coder CO. In the preferred embodiment, said partitions are blocks which have a square shape and all have the same size. As a function of the size of the image which is not necessarily a multiple of the size of the blocks, the last blocks on the left and the last blocks at the bottom may not be square. In an alternative embodiment, the blocks may be for example of rectangular size and/or not aligned one with another.

Each block or macroblock may moreover itself be divided into sub-blocks which are themselves subdividable.

Such an identification is performed by a stream analysis software module EX_DO, such as represented in FIG. **6**.

In the course of a step SD**1** represented in FIG. **5**, the module EX_DO of FIG. **6** selects as current block B_i the first block B_1 to be decoded. Such a selection consists for example in placing a pointer for reading in the signal F at the start of the data of the first block B_1.

There is thereafter undertaken the decoding of each of the selected coded blocks.

In the example represented in FIG. **5**, such a decoding is applied successively to each of the coded blocks B_1 to B_Z. The blocks are decoded according to for example a "raster scan" traversal well known to the person skilled in the art.

The decoding according to the invention is implemented in a decoding software module MD_DO of the decoder DO, such as represented in FIG. **6**.

In the course of a step SD**2** represented in FIG. **5**, there is firstly undertaken the entropy decoding of the first current block B_1 which has been selected. Such an operation is performed by an entropy decoding module DE_DO represented in FIG. **6**, for example of CABAC type. In the course of this step, the module DE_DO performs an entropy decoding of the items of digital information corresponding to the amplitude of each of the coded data of the list D_1 or of the modified list Dm_1. At this juncture, only the signs of the data of the list D_1 or of the modified list Dm_1 are not decoded.

In the case where the processing module MTR_DO receives the list $D_1=(a_1, a_2, \ldots, a_P)$, there is undertaken, in the course of a step SD**3** represented in FIG. **5**, a conventional entropy decoding of all the signs of the data of the list D_1. Such a decoding is performed by the CABAC decoder, designated by the reference DE_DO in FIG. **6**. For this purpose, the sign of each non-zero data item of the list D_1 is decoded entropically.

In the case where the processing module MTR_DO receives the modified list $Dm_1=(a'_1, a'_2, \ldots, a'_P)$, there is undertaken, in the course of said step SD**3**, the conventional entropy decoding of all the signs of the data of the list Dm_1, with the exception of the sign of the first non-zero data item a2.

In the course of a step SD**4** represented in FIG. **5**, the processing module MTR_DO calculates the value of a function f which is representative of the data of the list Dm_1, so as to determine whether the calculated value is even or odd.

In the preferred embodiment where a single sign is hidden in the signal F, the function f is the parity of the sum of the data of the list Dm_1.

In accordance with the convention used at the coder CO, which is the same at the decoder DO, an even value of the sum of the data of the list Dm_1 signifies that the sign of the first non-zero data item of the modified list Dm_1 is positive, while an odd value of the sum of the data of the list Dm_1 signifies that the sign of the first non-zero data item of the modified list Dm_1 is negative.

In the exemplary embodiment, the total sum of the data is even. Consequently, on completion of step SD**4**, the processing module MTR_DO deduces therefrom that the hidden sign of the first non-zero data item a2 is positive.

In the course of a step SD**5** represented in FIG. **5**, there is undertaken the construction of the decoded block BD_1. Such an operation is performed by a reconstruction software module MR_DO represented in FIG. **6**.

In the course of a step SD**6** represented in FIG. **5**, the decoding module MD_DO tests whether the decoded current block is the last block identified in the signal F.

If the current block is the last block of the signal F, in the course of a step SD**7** represented in FIG. **5**, the decoding method is terminated.

If such is not the case, there is undertaken the selection of the following block B_i to be decoded, in accordance with the aforementioned raster scan order of traversal, by iteration of steps SD**1** to SD**5**, for $1 \leq i \leq Z$.

Another embodiment of the invention will now be described, mainly with reference to FIG. **5**.

This other embodiment is distinguished from the previous one solely by the number of hidden signs which is now equal to N, N being an integer such that $N \geq 2$.

For this purpose, in the course of the aforementioned step SD**3**, there is undertaken the conventional entropy decoding of all the signs of the data of the list Dm_1, with the exception of the N respective signs of the first few non-zero data of said modified list Dm_1, said N signs being hidden.

In this other embodiment, the processing module MTR_DO calculates, in the course of step SD**4**, the value of the function f which is the remainder modulo 2^N of the sum of the data of the list Dm_1. It is assumed that in the example proposed, N=2.

The processing module MTR_DO then deduces therefrom the configuration of the two hidden signs which are allotted

respectively to each of the first two non-zero data a2 and a3, according to the convention used on coding.

Once these two signs have been reconstructed, there is undertaken the implementation of steps SD**5** to SD**7** described hereinabove.

A particular embodiment of the decoding method according to the invention will now be described, in which the decoding method is implemented in a software or hardware manner by modifications of a decoder initially complying with the H.264/MPEG-4 AVC standard.

The decoding method according to the invention is represented in the form of an algorithm comprising steps D**1** to D**12** represented in FIG. **7**.

According to the embodiment of the invention, the decoding method according to the invention is implemented in a decoding device or decoder DO**1**, such as represented in FIG. **8**, which is able to process the signal F' delivered by the coder CO**1** of FIG. **4**.

In the course of a preliminary step, not represented in FIG. **7**, there is undertaken the identification, in the data signal F' received, of the partitions B'_1 to B'_Z which have been coded previously by the coder CO**1**. In the preferred embodiment, said partitions are blocks which have a square shape and all have the same size. As a function of the size of the image which is not necessarily a multiple of the size of the blocks, the last blocks on the left and the last blocks at the bottom may not be square. In an alternative embodiment, the blocks may be for example of rectangular size and/or not aligned one with another.

Each block or macroblock may moreover itself be divided into sub-blocks which are themselves subdividable.

Such an identification is performed by a stream analysis software module EX_DO**1**, such as represented in FIG. **8**.

In the course of a step D**1** represented in FIG. **7**, the module EX_DO**1** of FIG. **8** selects as current block B'_1 the first block B'_1 to be decoded. Such a selection consists for example in placing a pointer for reading in the signal F' at the start of the data of the first block B'_1.

There is thereafter undertaken the decoding of each of the selected coded blocks.

In the example represented in FIG. **7**, such a decoding is applied successively to each of the coded blocks B'_1 to B'_Z. The blocks are decoded according to for example a "raster scan" traversal well known to the person skilled in the art.

The decoding according to the invention is implemented in a decoding software module MD_DO**1** of the decoder DO**1**, such as represented in FIG. **8**.

In the course of a step D**2** represented in FIG. **7**, there is firstly undertaken the entropy decoding of the first current block B'_1 which has been selected. Such an operation is performed by an entropy decoding module DE_DO**1** represented in FIG. **8**, for example of CABAC type. In the course of this step, the module DE_DO**1** performs an entropy decoding of the digital information corresponding to the amplitude of each of the coded coefficients of the list E_1 or of the modified list Em_1. At this juncture, only the signs of the coefficients of the list E_1 or of the modified list Em_1 are not decoded.

In the course of a step D**3** represented in FIG. **7**, there is undertaken the determination of the number of signs liable to have been hidden in the course of the previous step of entropy coding C**20**. Such a step D**3** is performed by a processing software module MTR_DO**1**, such as represented in FIG. **8**. Step D**3** is similar to the aforementioned step C**7** of determining the number of signs to be hidden.

In the preferred embodiment, the number of hidden signs is one or zero. Furthermore, in accordance with said preferred embodiment, it is the sign of the first non-zero coefficient which is hidden. In the example represented, this therefore entails the positive sign of the coefficient $\epsilon 2$=+9.

In an alternative embodiment, the number of hidden signs is either zero, or one, or two, or three, or more.

In accordance with the preferred embodiment of step D**3**, there is undertaken, in the course of a first sub-step D**31** represented in FIG. **7**, the determination, on the basis of said list E_1 or of the modified list Em_1, of a sub-list containing coefficients $\epsilon'1, \epsilon'2, \ldots, \epsilon'M$ where M<L liable to have been modified on coding.

Such a determination is performed in the same manner as in the aforementioned coding step C**7**.

Like the aforementioned processing module MTR_CO**1**, the processing module MTR_DO**1** is configured initially so as not to modify:

- the zero coefficient or coefficients situated before the first non-zero coefficient,
- and for calculation complexity reasons, the zero coefficient or coefficients situated after the last non-zero coefficient.

In the example represented, on completion of sub-step D**31**, this entails the sub-list SEm_1 such that SEm_1=(9, −6, 0, 0, 1, 0, −1, 2, 0, 0, 1). Consequently, eleven coefficients liable to have been modified are obtained.

In the course of a following sub-step D**32** represented in FIG. **7**, the processing module MTR_DO**1** undertakes the comparison of the number of coefficients liable to have been modified with a predetermined threshold TSIG. In the preferred embodiment, TSIG equals 4.

If the number of coefficients liable to have been modified is less than the threshold TSIG, there is undertaken, in the course of a step D**4** represented in FIG. **7**, a conventional entropy decoding of all the signs of the coefficients of the list E_1. Such a decoding is performed by the CABAC decoder, designated by the reference DE_DO**1** in FIG. **8**. For this purpose, the sign of each non-zero coefficient of the list E_1 is decoded entropically.

If the number of coefficients liable to have been modified is greater than the threshold TSIG, there is undertaken, in the course of said step D**4**, the conventional entropy decoding of all the signs of the coefficients of the list Em_1, with the exception of the sign of the first non-zero coefficient $\epsilon 2$.

In the course of a step D**5** represented in FIG. **7**, the processing module MTR_DO**1** calculates the value of a function f which is representative of the coefficients of the sub-list SEm_1 so as to determine whether the calculated value is even or odd.

In the preferred embodiment where a single sign is hidden in the signal F', the function f is the parity of the sum of the coefficients of the sub-list SEm_1.

In accordance with the convention used at the coder CO**1**, which is the same at the decoder DO**1**, an even value of the sum of the coefficients of the sub-list SEm_1 signifies that the sign of the first non-zero coefficient of the modified list Em_1 is positive, while an odd value of the sum of the coefficients of the sub-list SEm_1 signifies that the sign of the first non-zero coefficient of the modified list Em_1 is negative.

In the exemplary embodiment where SEm_1=(+9,−6,0,0,+1,0,−1,+2,0,0,+1), the total sum of the coefficients is equal to 6, and is therefore even. Consequently, on completion of step D**5**, the processing module MTR_DO**1** deduces therefrom that the hidden sign of the first non-zero coefficient $\epsilon 2$ is positive.

In the course of a step D**06** represented in FIG. **7**, and with the aid of all the items of digital information reconstructed in the course of steps D**2**, D**4** and D**5**, there is undertaken the reconstruction of the quantized coefficients of the block $B'q_1$

in a predefined order. In the example represented, this entails a zig-zag traversal inverse to the zig-zag traversal performed in the course of the aforementioned coding step C**6**. Such a step is performed by a reading software module ML_DO**1**, such as represented in FIG. **8**. More precisely, the module ML_DO**1** undertakes the writing of the coefficients of the list E_1 (one-dimensional) to the block $B'q_1$ (two-dimensional), using said inverse zig-zag order of traversal.

In the course of a step D**7** represented in FIG. **7**, there is undertaken the dequantization of the quantized residual block $B'q_1$ according to a conventional dequantization operation which is the operation inverse to the quantization performed on coding in the aforementioned step C**5**, so as to produce a decoded dequantized block $BD'q_1$. Such a step is performed by means of a dequantization software module MDQ_DO**1**, such as represented in FIG. **8**.

In the course of a step D**8** represented in FIG. **7**, there is undertaken the inverse transformation of the dequantized block $BD'q_1$ which is the operation inverse to the direct transformation performed on coding in the aforementioned step C**4**. A decoded residual block $BD'r_1$ is then obtained. Such an operation is performed by an inverse transform software module MTI_DO**1**, such as represented in FIG. **8**.

In the course of a step D**9** represented in FIG. **7**, there is undertaken the predictive decoding of the current block B'_1. A predictive decoding such as this is performed conventionally by known techniques of intra and/or inter prediction, in the course of which the block B'_1 is predicted with respect to at least one previously decoded block. Such an operation is performed by a predictive decoding module PRED_DO**1** such as represented in FIG. **8**.

It goes without saying that other modes of intra prediction, such as are proposed in the H.264 standard, are possible.

In the course of this step, the predictive decoding is performed with the aid of the syntax elements decoded in the previous step and comprising in particular the type of prediction (inter or intra) and, if appropriate, the mode of intra prediction, the type of partitioning of a block or macroblock if the latter has been subdivided, the reference image index and the displacement vector used in the mode of inter prediction.

Said aforementioned predictive decoding step makes it possible to construct a predicted block $B'p_1$.

In the course of a step D**10** represented in FIG. **7**, there is undertaken the construction of the decoded block BD'_1 by adding the decoded residual block $BD'r_1$ to the predicted block $B'p_1$. Such an operation is performed by a reconstruction software module MR_DO**1** represented in FIG. **8**.

In the course of a step D**11** represented in FIG. **7**, the decoding module MD_DO**1** tests whether the decoded current block is the last block identified in the signal F'.

If the current block is the last block of the signal F', in the course of a step D**12** represented in FIG. **7**, the decoding method is terminated.

If such is not the case, there is undertaken the selection of the following block B'_1 to be decoded in accordance with the aforementioned raster scan order of traversal, by iteration of steps D**1** to D**10**, for $1 \leq i \leq Z$.

Another embodiment of the invention will now be described, mainly with reference to FIG. **7**.

This other embodiment is distinguished from the previous one solely by the number of hidden coefficients which is either 0, or N, N being an integer such that $N \geq 2$.

For this purpose, the aforementioned comparison sub-step D**32** is replaced with sub-step D**32***a* represented dashed in FIG. **7**, in the course of which there is undertaken the comparison of the number of coefficients liable to have been modified with several predetermined thresholds 0<TSIG_1<TSIG_2<TSIG_3 . . . , in such a way that if the number of said coefficients lies between TSIG_N and TSIG_N+1, N signs have been hidden.

If the number of said coefficients is less than the first threshold TSIG_1, there is undertaken, in the course of the aforementioned step D**4**, the conventional entropy decoding of all the signs of the coefficients of the list E_1. For this purpose, the sign of each non-zero coefficient of the list E_1 is decoded entropically.

If the number of said coefficients lies between the threshold TSIG_N and TSIG_N+1, there is undertaken, in the course of the aforementioned step D**4**, the conventional entropy decoding of all the signs of the coefficients of the list E_1, with the exception of the N respective signs of the first non-zero coefficients of said modified list Em_1, said N signs being hidden.

In this other embodiment, the processing module MTR_DO**1** calculates, in the course of step D**5**, the value of the function f which is the remainder modulo 2^N of the sum of the coefficients of the sub-list SEm_1. It is assumed that in the example proposed, N=2.

The processing module MTR_DO**1** then deduces therefrom the configuration of the two hidden signs which are allotted respectively to each of the first two non-zero coefficients $\epsilon 2$ and $\epsilon 3$, according to the convention used on coding.

Once these two signs have been reconstructed, steps D**6** to D**12** described hereinabove are carried out.

It goes without saying that the embodiments which have been described hereinabove have been given purely by way of indication and are not at all limiting, and that numerous modifications can easily be made by the person skilled in the art without however departing from the scope of the invention.

Thus for example, according to a simplified embodiment with respect to that represented in FIG. **4**, the coder CO**1** could be configured to hide at least N' predetermined signs, with $N' \geq 1$, instead of either zero, or one or N predetermined signs. In this case, the comparison step C**72** or C**72***a* would be dispensed with. In a corresponding manner, according to a simplified embodiment with respect to that represented in FIG. **8**, the decoder DO**1** would be configured to reconstruct N' predetermined signs instead of either zero, or one or N predetermined signs. In this case, the comparison step D**32** or D**32***a* would be dispensed with. Furthermore, the decision criterion applied in the coding step C**72** and in the decoding step D**32** could be replaced with another type of criterion. For this purpose, instead of comparing with a threshold the number of modifiable coefficients or the number of coefficients liable to have been modified, the processing module MTR_CO**1** or MTR_DO**1** could apply a decision criterion which is respectively dependent on the sum of the amplitudes of the coefficients that are modifiable or liable to have been modified, or else the number of zeros present among the coefficients that are modifiable or liable to have been modified.

The invention claimed is:

1. A computer-implemented method for decoding an image, the method comprising:

obtaining a set of coefficients representing a residual block of the image, the set of coefficients including a plurality of non-zero coefficients;

determining whether a count of modifiable coefficients in the set of coefficients is greater than a predetermined number, wherein modifiable coefficients in the set comprise a first non-zero coefficient according to a reverse scan order of the residual block, a last non-zero coefficient according to the reverse scan order, and the coef-

ficients between the first and the last non-zero coefficients in the set of coefficients according to the reverse scan order;

if the count of modifiable coefficients in the set of coefficients is less than or equal to the predetermined number, determining that a sign designation of the last non-zero coefficient according to the reverse scan order is not hidden; and

if the count of modifiable coefficients in the set of coefficients is greater than the predetermined number:

determining that the sign designation of the last non-zero coefficient is hidden, and

determining the sign designation for the last non-zero coefficient, comprising:

computing a sum of non-zero coefficients in the set of coefficients;

computing, using the sum of the non-zero coefficients, parity data; and

designating a sign for the last non-zero coefficient based on the parity data;

wherein the predetermined number is 4.

2. The method of claim **1**, wherein designating the sign for the last non-zero coefficient comprises:

determining that a value of the parity data is equal to a specific value assigned to a positive sign; and

in response to determining that the value of the parity data is equal to the specific value assigned to the positive sign, designating the positive sign for the last non-zero coefficient.

3. The method of claim **1**, wherein designating the sign for the last non-zero coefficient comprises:

determining that a value of the parity data is equal to a specific value assigned to a negative sign; and

in response to determining that the value of the parity data is equal to the specific value assigned to the negative sign, designating the negative sign for the last non-zero coefficient.

4. The method of claim **1**, comprising:

determining that a sign-data-hiding encoding is enabled for the set of coefficients.

5. A decoder for decoding a sign data hiding enabled partition of an image, comprising:

one or more processors; and

a computer-readable medium coupled to the one or more processors having instructions stored thereon which, when executed by the one or more processors, cause the one or more processors to perform operations comprising:

obtaining a set of coefficients representing a residual block of the image, the set of coefficients including a plurality of non-zero coefficients;

determining whether a count of modifiable coefficients in the set of coefficients is greater than a predetermined number, wherein modifiable coefficients in the set comprise a first non-zero coefficient according to a reverse scan order of the residual block, a last non-zero coefficient according to the reverse scan order, and the coefficients between the first and the last non-zero coefficients in the set of coefficients according to the reverse scan order;

if the count of modifiable coefficients in the set of coefficients is less than or equal to the predetermined number, determining that a sign designation of the last non-zero coefficient according to the reverse scan order is not hidden; and

if the count of modifiable coefficients in the set of coefficients is greater than the predetermined number:

determining that the sign designation of the last non-zero coefficient is hidden, and

determining the sign designation for the last non-zero coefficient, comprising:

computing a sum of non-zero coefficients in the set of coefficients;

computing, using the sum of the non-zero coefficients, parity data; and

designating a sign for the last non-zero coefficient based on the parity data;

wherein the predetermined number is 4.

6. The decoder of claim **5**, wherein designating the sign for the last non-zero coefficient comprises:

determining that a value of the parity data is equal to a specific value assigned to a positive sign; and

in response to determining that the value of the parity data is equal to the specific value assigned to the positive sign, designating the positive sign for the last non-zero coefficient.

7. The decoder of claim **5**, wherein designating the sign for the last non-zero coefficient comprises:

determining that a value of the parity data is equal to a specific value assigned to a negative sign; and

in response to determining that the value of the parity data is equal to the specific value assigned to the negative sign, designating the negative sign for the last non-zero coefficient.

8. The decoder of claim **5**, wherein the operations comprise:

determining that a sign-data-hiding encoding is enabled for the set of coefficients.

9. A computer-readable medium coupled to one or more processors having instructions stored thereon which, when executed by the one or more processors, cause the one or more processors to perform operations comprising:

obtaining a set of coefficients representing a residual block of the image, the set of coefficients including a plurality of non-zero coefficients;

determining whether a count of modifiable coefficients in the set of coefficients is greater than a predetermined number, wherein modifiable coefficients in the set comprise a first non-zero coefficient according to a reverse scan order of the residual block, a last non-zero coefficient according to the reverse scan order, and the coefficients between the first and the last non-zero coefficients in the set of coefficients according to the reverse scan order;

if the count of modifiable coefficients in the set of coefficients is less than or equal to the predetermined number, determining that a sign designation of the last non-zero coefficient according to the reverse scan order is not hidden; and

if the count of modifiable coefficients in the set of coefficients is greater than the predetermined number:

determining that the sign designation of the last non-zero coefficient is hidden, and

determining the sign designation for the last non-zero coefficient, comprising:

computing a sum of non-zero coefficients in the set of coefficients;

computing, using the sum of the non-zero coefficients, parity data; and

designating a sign for the last non-zero coefficient based on the parity data;

wherein the predetermined number is 4.

10. The computer-readable medium of claim 9, wherein designating the sign for the last non-zero coefficient comprises:

determining that a value of the parity data is equal to a specific value assigned to a positive sign; and

in response to determining that the value of the parity data is equal to the specific value assigned to the positive sign, designating the positive sign for the last non-zero coefficient.

11. The computer-readable medium of claim 9, wherein designating the sign for the last non-zero coefficient comprises:

determining that a value of the parity data is equal to a specific value assigned to a negative sign; and

in response to determining that the value of the parity data is equal to the specific value assigned to the negative sign, designating the negative sign for the last non-zero coefficient.

12. The computer-readable medium of claim 9, wherein the operations comprise:

determining that a sign-data-hiding encoding is enabled for the set of coefficients.

* * * * *